from the magnet in magnet portion **308***a* to create a force to move the bobbin relative to the magnet portion. The members **298***a* and **296***a* transmit the output force to the extension member **288***a*, which in turn transmits the force through central member **290***a* to manipulandum **282** about axis B. Second member **298***a* allows the linear motion of the bobbin **306***a* to be converted to a rotary motion through member **296***a* about axis B. Transducer system **294***b* has equivalent components to system **294***a* and operates in a similar manner to provide forces to manipulandum **282** about axis C. Therefore, in the described embodiment, actuators **300***a* and **300***b* are oriented approximately parallel to each other, such that the motion of the bobbin of one actuator in its linear degree of freedom is approximately parallel to the motion of the bobbin of the other actuator in its linear degree of freedom. Alternatively, the magnetic portions can be moved and the bobbins grounded. Furthermore, in the described embodiment, the direction of this linear motion of the actuators **300** is approximately orthogonal to the plane AB defined by axes A and B. This orientation of the actuators **300** can provide a more efficient layout for the actuators than if they were oriented in different directions. For example, the two actuators **300** can be positioned on a single circuit board or other support to save room in the housing of a device.

FIG. **12** is a block diagram illustrating a haptic feedback control device **320** and host computer **16** suitable for use with the present invention. Control device **320** can be any of the described embodiments, including controller **22**, **70**, **250**, or **280**. A system similar to that of FIG. **12** is described in detail in U.S. Pat. No. 5,734,373 which is hereby incorporated by reference herein in its entirety.

As explained with reference to FIG. **1**, computer **16** is preferably a personal computer, workstation, video game console, or other computing or display device. Host computer system **16** commonly includes a host microprocessor **322**, a clock **324**, a display device **17**, and an audio output device **326**. Host microprocessor **322** can include a variety of available microprocessors from Intel, AMD, Motorola, or other manufacturers. Microprocessor **322** can be single microprocessor chip, or can include multiple primary and/or co-processors and preferably retrieves and stores instructions and other necessary data from random access memory (RAM) and read-only memory (ROM) as is well known to those skilled in the art. In the described embodiment, host computer system **16** can receive sensor data or a sensor signal via bus **321** from sensors of device **320** and other information. Microprocessor **322** can receive data from bus **321** using I/O electronics, and can use the I/O electronics to control other peripheral devices. Host computer system **16** can also output commands to interface device **320** via bus **321** to cause haptic feedback.

Clock **324** can be a standard clock crystal or equivalent component used by host computer **16** to provide timing to electrical signals used by host microprocessor **322** and other components of the computer system **16** and can be used to provide timing information that may be necessary in determining force or position values. Display device **17** is described with reference to FIG. **10***a*. Audio output device **326**, such as speakers, can be coupled to host microprocessor **322** via amplifiers, filters, and other circuitry well known to those skilled in the art. Other types of peripherals can also be coupled to host processor **322**, such as storage devices (hard disk drive, CD ROM drive, floppy disk drive, etc.), printers, and other input and output devices. Slave **14** can also be considered a peripheral in the telemanipulator system **10**.

Control device **320** is coupled to host computer system **16** by a bi-directional bus **321**. The bi-directional bus sends signals in either direction between host computer system **16** and the interface device **320**. Bus **321** can be a serial interface bus, such as USB, RS-232, or Firewire (IEEE 1394), providing data according to a serial communication protocol, a parallel bus using a parallel protocol, or other types of buses. An interface port of host computer system **16**, such as a USB or RS232 serial interface port, can connect bus **21** to host computer system **16**.

Control device **320** can include a local microprocessor **330**, local clock **332**, local memory **334**, sensor interface **336**, and actuator interface **338**. Device **320** may also include additional electronic components for communicating via standard protocols on bus **321**.

Local microprocessor **330** preferably coupled to bus **321** and is considered "local" to device **320**, where "local" herein refers to processor **330** being a separate microprocessor from any processors **322** in host computer **16**. "Local" also preferably refers to processor **330** being dedicated to haptic feedback and sensor I/O of the device **320**, and being closely coupled to sensors and actuators of the device **320**, such as within the housing **74** or **256**. Microprocessor **330** can be provided with software instructions to wait for commands or requests from computer host **16**, parse/decode the command or request, and handle/control input and output signals according to the command or request. In addition, processor **330** can operate independently of host computer **16** by reading sensor signals and calculating appropriate forces from those sensor signals, time signals, and force processes selected in accordance with a host command, and outputting appropriate control signals to the actuators. Suitable microprocessors for use as local microprocessor **330** include the 8X930AX by Intel, the MC68HC711E9 by Motorola or the PIC16C74 by Microchip, for example. Microprocessor **330** can include one microprocessor chip, or multiple processors and/or co-processor chips. In other embodiments, microprocessor **330** can include digital signal processor (DSP) functionality, or be implemented as control logic components or hardware state machine instead of an actual microprocessor chip.

For example, in one host-controlled embodiment that utilizes microprocessor **330**, host computer **16** can provide low-level force commands over bus **321**, which microprocessor **330** directly transmits to the actuators. In a different local control embodiment, host computer system **16** provides high level supervisory commands to microprocessor **330** over bus **321**, and microprocessor **330** manages low level force control loops to sensors and actuators in accordance with the high level commands and independently of the host computer **16**. In the local control embodiment, the microprocessor **330** can process sensor signals to determine appropriate output actuator signals by following the instructions of a "force process" that may be stored in local memory **334** and includes calculation instructions, conditions, formulas, force magnitudes, or other data. The force process can command distinct force sensations, such as vibrations, textures, jolts, or even simulated interactions between displayed objects. The host can send the local processor **330** a spatial layout of objects in the graphical environment so that the microprocessor has a mapping of locations of graphical objects and can determine force interactions locally. Force feedback used in such embodiments is described in greater detail in co-pending patent application Ser. No. 08/879,296 and U.S. Pat. No. 5,734,373, both of which are incorporated by reference herein.

A local clock **332** can be coupled to the microprocessor **330** to provide timing data, similar to system clock **324** of host computer **18**; the timing data might be required, for example, to compute forces output by actuators **342**. Local memory